



# AIR QUALITY FORT FRANCES

Annual Report, 1978



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AIR QUALITY

FORT FRANCES

Annual Report, 1978

TECHNICAL SUPPORT SECTION  
NORTHWESTERN REGION  
ONTARIO MINISTRY OF THE ENVIRONMENT  
October, 1979

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## SUMMARY

Air quality studies in Fort Frances, begun by the Ontario Ministry of the Environment in 1972, continued in 1978 with a programme which included vegetation assessment, snow sampling and air quality monitoring.

Vegetation damage attributed to airborne emissions from a kraft pulp mill in Fort Frances occurred over an area similar in size to that found in 1976 and 1977. Injury symptoms on tree foliage were more severe in 1978 than in recent past years, possibly because of the combined effects of air pollutants and a significant infestation of forest tent caterpillar. Sodium and chloride concentrations in leaf tissue of Manitoba maple continued to be recorded at elevated levels near the Canadian mill. Calcium, sodium, and sulphate were also above normal levels in snow collected from the same area.

Dustfall regularly exceeded Ontario regulations near the Fort Frances mill. Saltcake, wood fines and road dust were major dustfall components. In the same locality, concentrations of suspended particulate matter also sometimes exceeded the acceptable limit.

Very high concentrations of total reduced sulphur (TRS) persisted in 1978 in the vicinity of the Fort Frances mill. TRS exceeded the Ontario guideline on more than 1000 occasions during the year, with a maximum value 20 times the guideline. Reduced sulphur compounds give rise to offensive odours at low concentrations and may cause temporary health effects, such as respiratory irritation, at the highest levels found in Fort Frances.

Control equipment to substantially reduce TRS emissions from the Fort Frances mill has been installed and will begin to be commissioned in late 1979. Improvements in the recovery furnace precipitator are under way to reduce fallout of saltcake. The

mill also plans to acquire screening devices to remove fine particles from wood chips to help reduce the problem of blowing sawdust and other wood fines. These three abatement projects are expected to result in significant improvement in local air quality. Progress in achieving this objective will be documented by continued Ministry monitoring programmes.

## INTRODUCTION

In 1972, the Ontario Ministry of the Environment began air quality studies in Fort Frances to assess the effects of airborne pollutants from operations at a bleached kraft pulp mill constructed in 1971 near a residential area.

Investigations up to 1977 (1, 2, 3) documented that emissions from the mill often resulted in excessive concentrations of particulate matter and malodorous gases, localized vegetation damage, and numerous complaints from nearby residents. Acquisition of a "buffer-zone" by the mill overcame some of the acute complaint problems, and improved plant operating procedures reduced periodic upset conditions which had resulted in several damaging contaminant releases during the early years of mill operation.

The Ministry's 1978 air quality assessment programme continued along the same lines adopted in earlier years, and included vegetation studies, snow sampling, and air quality monitoring.

## VEGETATION ASSESSMENT

### VEGETATION INJURY

Because of its widespread local occurrence and apparent sensitivity to injury, Manitoba maple (*Acer negundo*) is used as an indicator species in assessing the degree and extent of vegetation damage from contaminants emitted from the pulp mills in Fort Frances and in neighbouring International Falls, Minnesota. Based on visible injury to Manitoba maple foliage, the 1978 "injury zone" was about 9 ha (hectares), compared with 12 ha in 1977, 8 in 1976, 20 in 1975 and 26 in 1974. All injury was attributed to emissions from the Fort Frances Mill (Figure 1). White elm, basswood, ash, *Viburnum*, lilac, and honeysuckle near the mill all showed symptoms of air pollution injury. Most of damage, which

was judged to be more severe than in 1977, was confined to the mill's buffer zone. Some of the vegetation in the buffer zone showed evidence of progressive dieback. A significant amount of insect damage, mostly caused by forest tent caterpillars, was also noted in the general area and some trees showed simultaneous evidence of insect attack and air pollution injury. The caterpillar infestation occurred early in the growing season, with most of the air pollution effects appearing in mid-summer. Some of the Manitoba maple foliage near the Fort Frances mill was also infected with a leaf-spot disease caused by *Rhytisma punctatum*.

#### CHEMICAL ANALYSIS

Triplicate samples of Manitoba maple foliage were collected in August from 43 sites (Figure 2) plus two controls about 4 km (kilometres) from both pulp mills. Sampling, sample processing, and analytical methods for chloride, sodium and sulphur content in foliage were the same as those described for 1977 (3). Sulphur concentrations were found to be slightly elevated (about 0.40 to 0.45 percent, dry weight) near the Fort Frances mill compared to background values (0.25 to 0.30 percent) at the control sites. Chloride and sodium results are given in Table 1, along with data for earlier years. Foliar concentrations of chloride were significantly elevated at sites closest to the Canadian mill, and decreased rapidly to normal levels at a distance of about 300 m (metres). As in 1977, highest values were from samples collected immediately north and northeast of the mill (Figure 3). Sodium concentrations in Manitoba maple (Figure 4) near the mill were similar to those in previous years, and exceeded the Ministry guideline of 600 µg/g (micrograms of sodium per gram of dried foliage) on the Company-owned buffer zone. Sodium levels elsewhere in Fort Frances and in International Falls were normal.



The specific causes of vegetation damage near the Fort Frances mill have still not been resolved. Although the highest chloride and sodium level in tree foliage are usually found in the area where injury is most severe, neither chloride nor sodium are thought to be major contributors to local vegetation damage (3). Recent experimental evidence (4) has documented the adverse effects of hydrogen sulphide ( $H_2S$ ) on sensitive vegetation at concentrations as low as 300 ppb (parts per billion). Hydrogen sulphide and other organic sulphides, which are known to occur at levels of 300 ppb or more in the injury zone near the Fort Frances mill, are now under investigation as possible primary causes of damage to local plant life.

#### SNOW SAMPLING

The Ministry has undertaken snow sampling surveys for several years in Fort Frances to assess the identity and extent of the deposition of particulate matter around the two pulp mills. These studies have revealed very high concentrations of carbon, sodium, and sulphate, and moderately elevated levels of calcium in snow north and east of the Fort Frances mill (1, 2, 3). In 1978, a reduced survey at 11 sites (Figure 5) was undertaken to further document the situation. Samples were collected and processed by standard Ministry methods (3) and were analysed for several parameters at the Ministry's Thunder Bay and Toronto laboratories.

The 1978 data are compared, in Table 2, with average values for snow surveys in the 1974 to 1977 period. The 1978 chloride concentrations were about the same as before. Although calcium, sodium and sulphate had declined, most values were still well above the contaminant guidelines. Acidity was low throughout the study area, while alkalinity, conductivity and suspended solids were elevated near the mills (Table 3). The only elevated reading for tannins, at site 7, was attributed to fallout of wood fines from a nearby overhead chip conveyor.

## AIR QUALITY MONITORING

### PARTICULATE POLLUTANTS

#### Dustfall

Dustfall, which comprises particulate matter that settles out from the atmosphere by gravity, has been monitored in Fort Frances since 1972. Details of the measurement method appear in the 1977 air quality report (3). In 1978, dustfall from eight sites (Figure 6) was analysed for soluble calcium, chloride, sodium and sulphate. Total dustfall frequently exceeded the Ontario monthly objective at sites near the Fort Frances mill (Table 4, Figure 7a). The annual objective was met only at the two most distant locations. Average dustfall was lower in 1978 than 1977, but this decline may have been partly due to reduced pulp production at the mill in the last 2½ months of the year. There was no evidence that operations at the U.S. mill had any influence on Fort Frances dustfall levels.

Levels of chloride in dustfall were mostly low ( $<0.1 \text{ g/m}^2/30 \text{ days}$ ), but calcium, sodium and sulphate (Tables 5, 6 and 7) occurred at significantly higher concentrations near the mill than at distant sites. Expressed as saltcake ( $\text{Na}_2\text{SO}_4$ ), a known contaminant emitted by the mill, sulphate accounted for about 35 percent of dustfall at station 62033 (nearest the mill) and about 15 percent of dustfall at other sites. Wood fines and re-entrained road dust also probably contributed to total dustfall, particularly at station 62036.

To reduce saltcake fallout, the mill is rebuilding the recovery furnace precipitator in a two-stage programme scheduled for completion in the spring of 1980. Later, screening devices are to be installed to remove fine particles from wood chips, thus reducing emissions of airborne wood fines from this source. If successful, these abatement measures should significantly decrease the nuisance caused by high levels of particulate matter around the Canadian mill.

## Suspended Particulate

Measurement of suspended particulate with high-volume samplers has been conducted regularly in Fort Frances since late 1975. Details of the procedure are outlined in the 1977 air quality report (3).

Values for 1978 recorded by the two monitors (Table 8) were similar to those obtained in 1977. At station 62030, near the mill, the 24-hour Ontario objective of  $120 \mu\text{g}/\text{m}^3$  (micrograms of particulate matter per cubic metre of air) was exceeded 11 times, compared to eight times in 1977. Most excursions above the objective occurred in the spring and fall. The annual average of  $57 \mu\text{g}/\text{m}^3$  was within the Ontario regulation of  $60 \mu\text{g}/\text{m}^3$ . Average particulate levels were highest ( $97 \mu\text{g}/\text{m}^3$ ) with southerly prevailing wind from the Fort Frances mill and lowest ( $54 \mu\text{g}/\text{m}^3$ ) with northerly wind, thus implicating the mill area as a source of fine particulate matter. Filters carrying particulate loadings exceeding the 24-hour objective were examined to identify visible contaminants. Wood fines were observed on filters exposed on June 19, September 23, October 11, October 17 and November 22. Filters for the period April 8 to May 2 contained mostly road dust. At station 62032, in a non-industrial area some distance from the mill, all but one of the 24-hour values complied with the provincial regulation. The annual average of  $30 \mu\text{g}/\text{m}^3$  was well below the maximum acceptable level of  $60 \mu\text{g}/\text{m}^3$ , and there was no significant difference in particulate loadings with different prevailing winds.

## GASEOUS POLLUTANTS

### Sulphation Rates

A crude, semi-quantitative measure of average levels of sulphur-containing gases in the air can be obtained by exposing lead dioxide-coated plastic dishes to the atmosphere for specified

periods. The method, described in more detail in the 1977 report (3), does not discriminate between different reactive sulphur compounds and produces readings when any such pollutant is present in sufficient concentration. In Fort Frances, sulphur dioxide concentrations are considered negligible (1) and the sulphation rate data are therefore regarded as estimates of average levels of hydrogen sulphide and other malodorous reduced sulphur compounds.

The 1978 data, in Table 9 and Figure 7b, show that highest sulphation rates occurred near the Fort Frances mill, and decreased as distance from this source increased. The lowest average was recorded at the east end of town (station 62037). Results for 1977 were similar. Based on the relationship between sulphation rates and average concentrations of reduced sulphur compounds determined with a continuous analyser at station 62030, a sulphation rate exceeding about  $0.20 \text{ mgSO}_3/100 \text{ cm}^2/\text{day}$  is considered to indicate undesirably high community odour levels.

#### Total Reduced Sulphur

Total reduced sulphur, or TRS, comprises a group of malodorous sulphur gases which are commonly associated with emissions from kraft pulp mills. The presence in the atmosphere of even very low concentrations of these pollutants will create offensive odours similar to those emitted by rotten eggs, decaying cabbage, or skunks. Higher concentrations may blacken lead-based paint, cause vegetation damage, or produce temporary health effects such as breathing discomfort, eye irritation, nausea, headache or sleep loss.

During the year, the Ministry operated coulometric titration analysers (Philips models 9700 and 9780) at stations 62030 and 62032. These monitors respond to hydrogen sulphide, methyl and ethyl mercaptan, and dimethyl sulphide. The range of the instrument at site 62030 was about 0-750 ppb (parts per billion) with a detection limit of about 8 ppb, and the analyser at station 62032 was operated at a 0-300 ppb range, with a detection limit of approximately 3 ppb.

The 1978 data are summarized in Table 10, and Figures 8 and 9. At station 62030, near the Fort Frances mill, there were 1011 excursions above the Ontario guideline of 27 ppb, hourly average. Measurable TRS concentrations were obtained 47 percent of the time, with the guideline exceeded 14 percent of the time. The maximum hourly average was 540 ppb, about 20 times the guideline. Overall results were similar in 1977. For months with complete or nearly complete data, November had by far the lowest readings. During the first part of November, the mill was not operating and for the remainder of the month, it operated at about 70 percent capacity. An analysis of TRS levels and wind direction (Table 11) shows that most of the high pollution concentrations were recorded with winds from the Fort Frances mill (170-220°) with lower levels associated with winds from the International Falls plant (240-260°). Concentrations with winds from other directions were usually negligible, except for some low values obtained with northwest winds. Odours from the mill's effluent lagoon or from one of the town's sewage pumping stations are thought to be responsible for the low readings from the northwest.

At station 62032, TRS exceeded the guideline for 141 hours (2 percent of the time), with a maximum hourly value of 134 ppb. Wind direction analysis (Table 12) indicated that the Fort Frances mill (110-120°) was as significant a source as the U.S. mill (140-170°), even though it was about twice the distance from the monitor. Some low readings were reported with northerly wind from the Canadian mill's effluent lagoon.

The odour levels near the Fort Frances mill are considered to be of sufficient concentration to cause short-term health effects. The most susceptible individuals would be infants, the aged, and those suffering from respiratory ailments. Symptoms of discomfort, described earlier in this report, might appear at TRS concentrations above 100 ppb, but would disappear with a reduction in TRS brought

about by a change in wind direction or by a decrease in emissions from the source. The Ministry of the Environment is not aware of any evidence of chronic, long-term health effects due to exposure to TRS in communities near pulp mills.

Equipment to substantially reduce TRS emissions from the Fort Frances mill was brought into operation in September, 1979. After an initial commissioning period, these controls are expected to bring about a permanent and significant improvement in local air quality.

#### ACKNOWLEDGEMENT

The Ministry wishes to thank staff of the Ministry of Industry and Tourism, Fort Frances, for assistance in operating the TRS monitor at station 62030.

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4. Thompson, C. R. and G. Kats. 1978. Effects of continuous  $H_2S$  fumigation on crop and forest plants. Environ. Sci. Technol. 12 : 550-553.

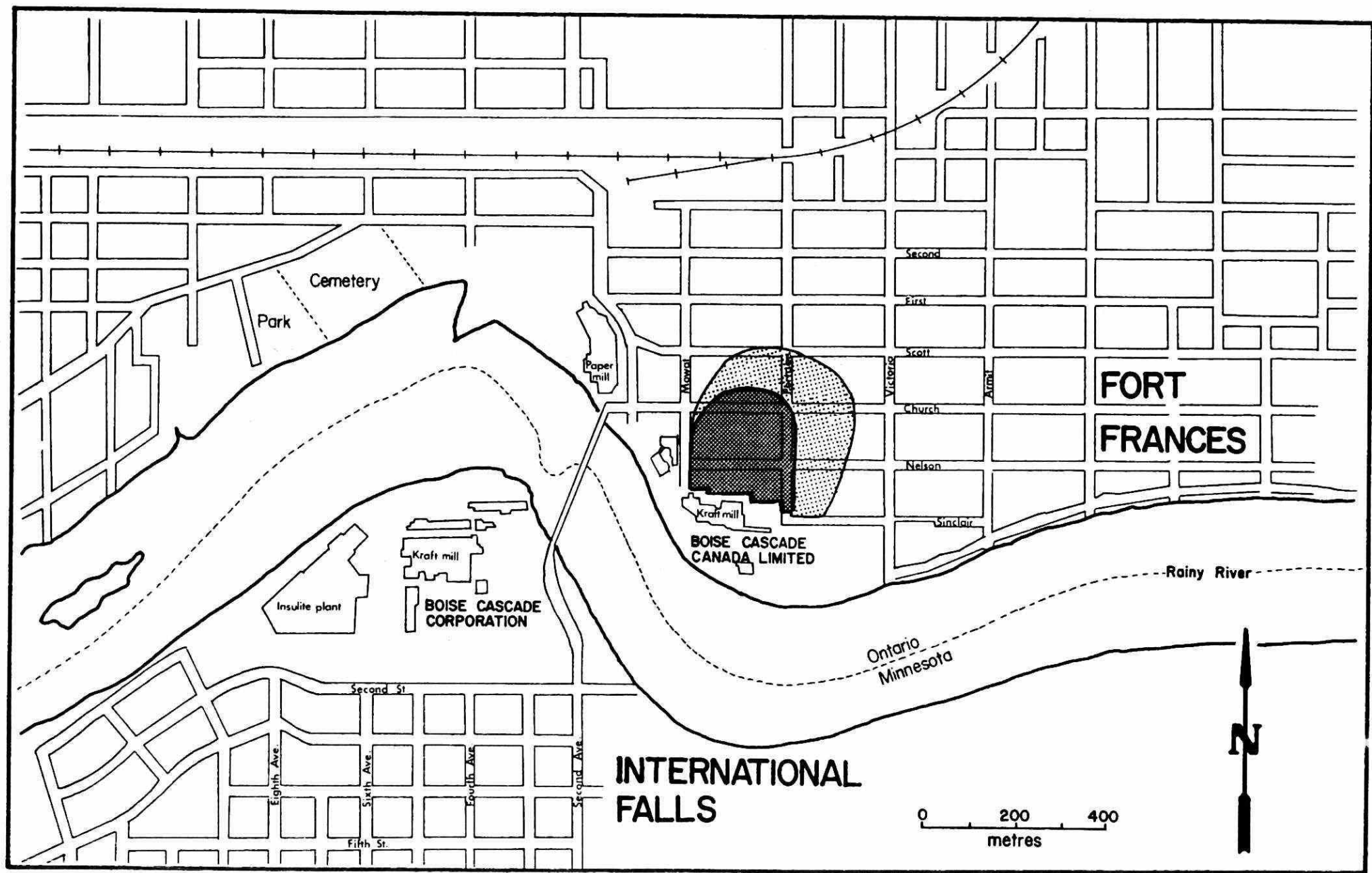


Figure 1. Zone of air pollution injury to Manitoba maple, August, 1978.

[Solid black box] Moderate to severe  
 [Stippled box] Trace to light



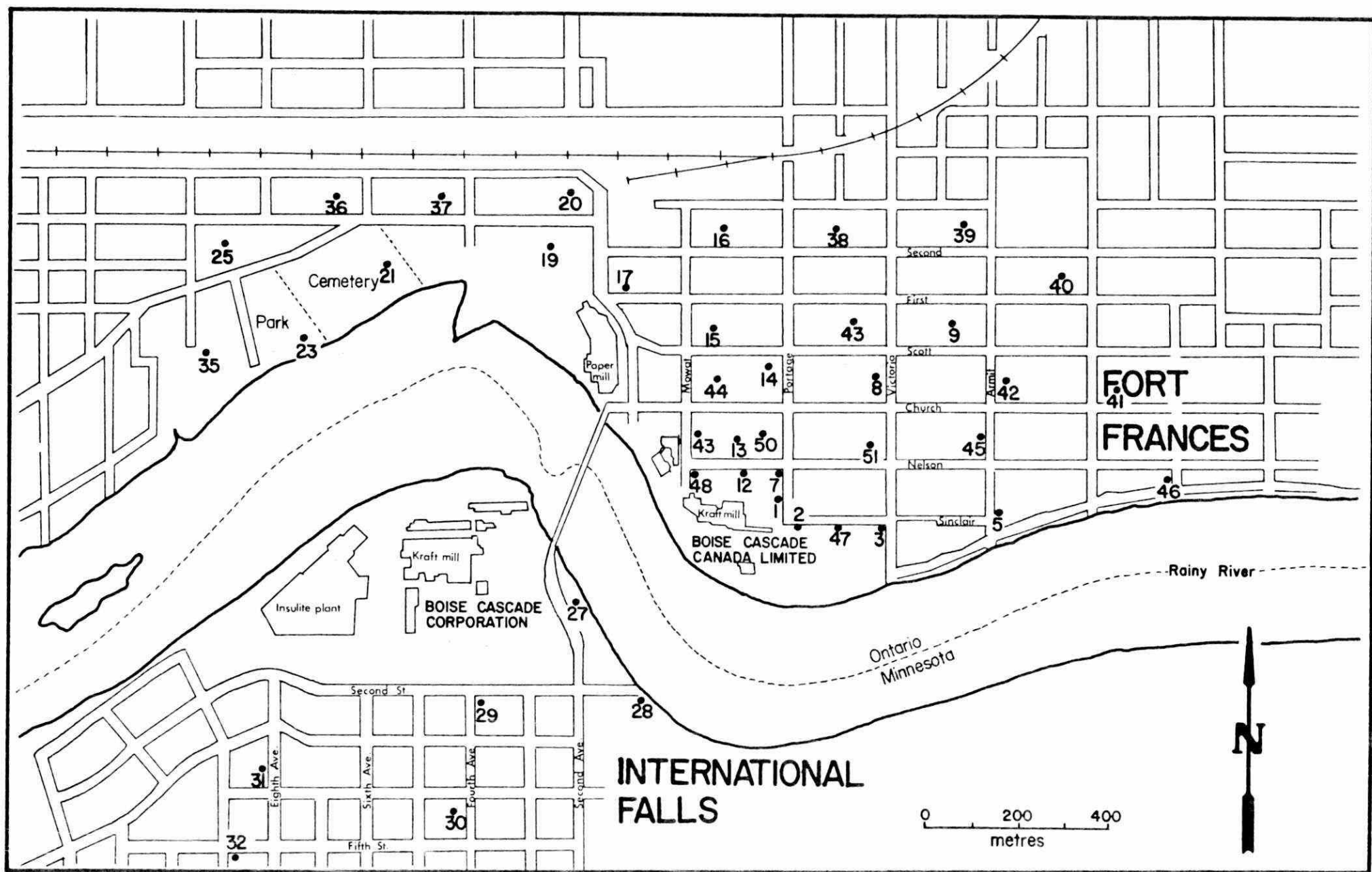


Figure 2. Manitoba maple sampling sites , 1978.



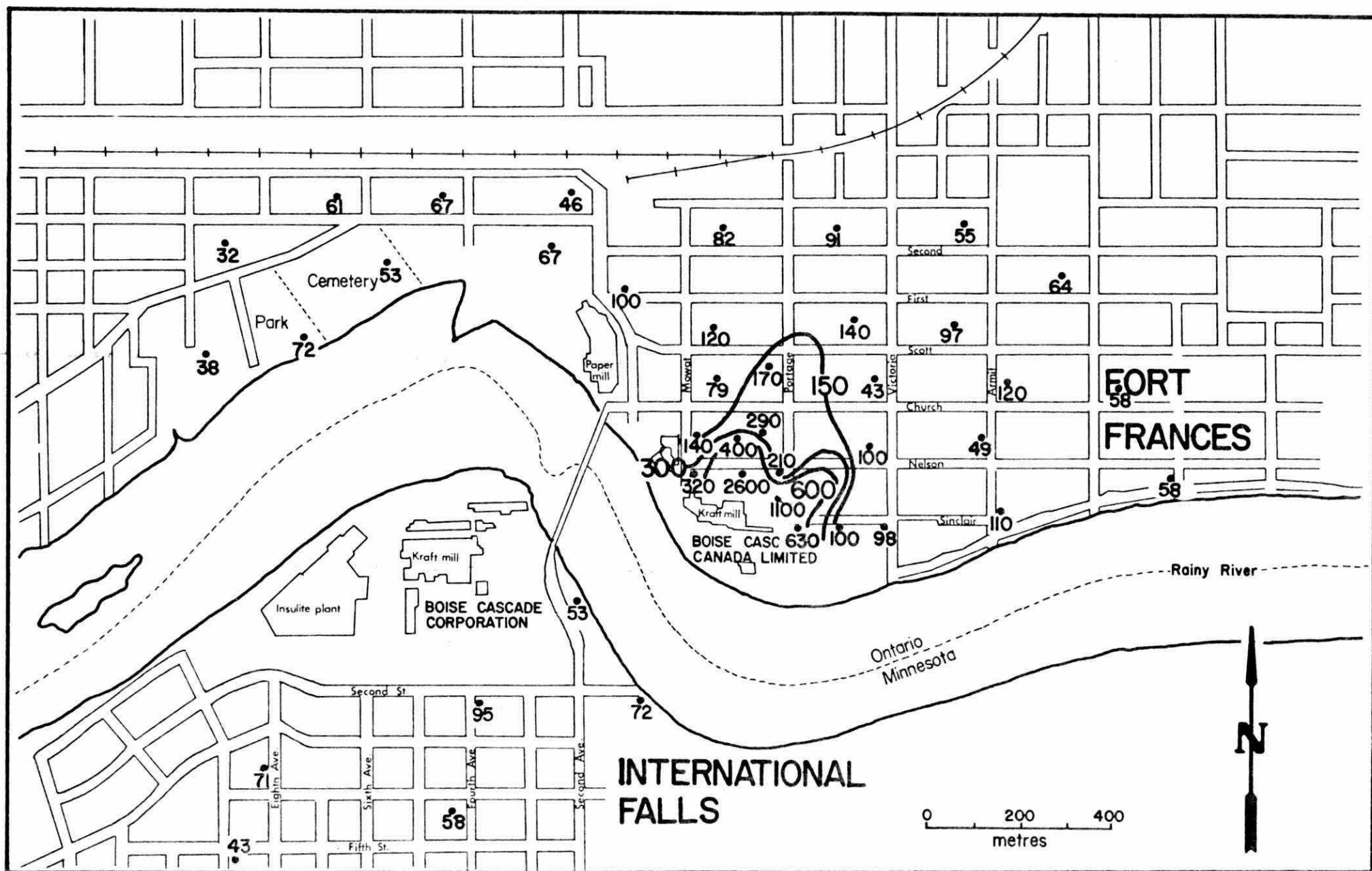


Figure 4. Average sodium levels ( $\mu\text{g/g}$ , dry weight) in Manitoba maple foliage, August, 1978.

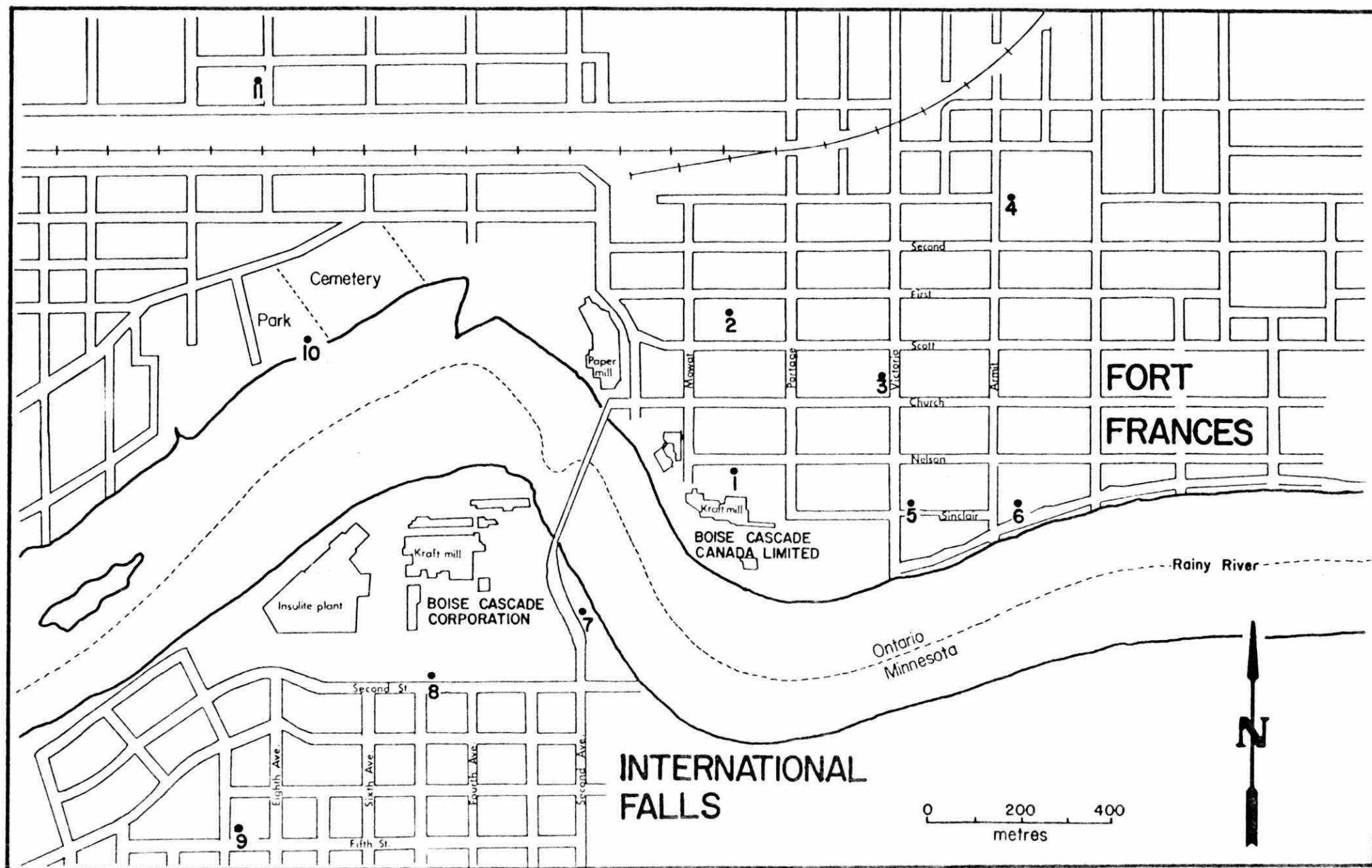


Figure 5. Snow sampling sites, 1978.

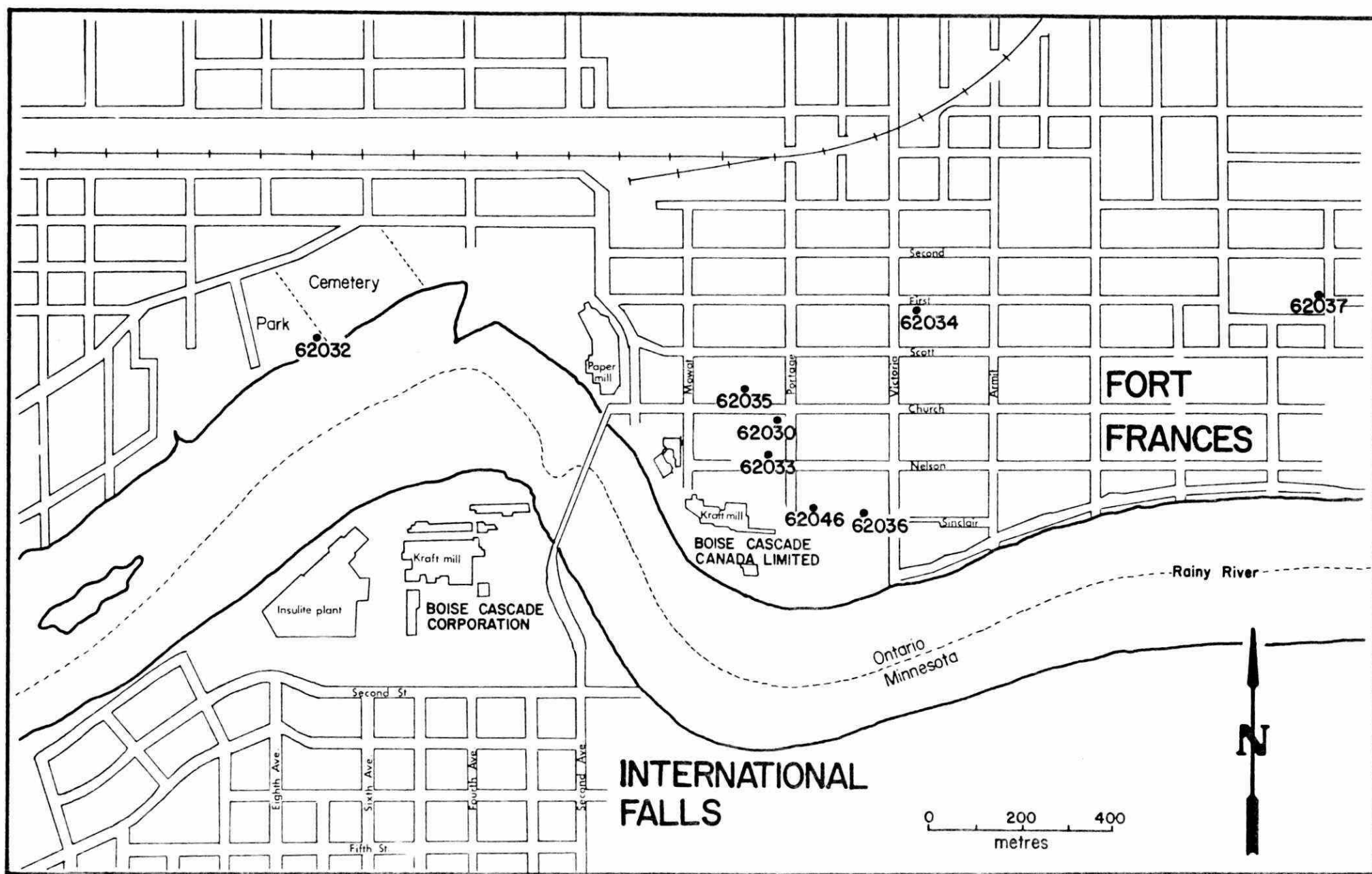


Figure 6. Air quality monitoring sites, 1978.



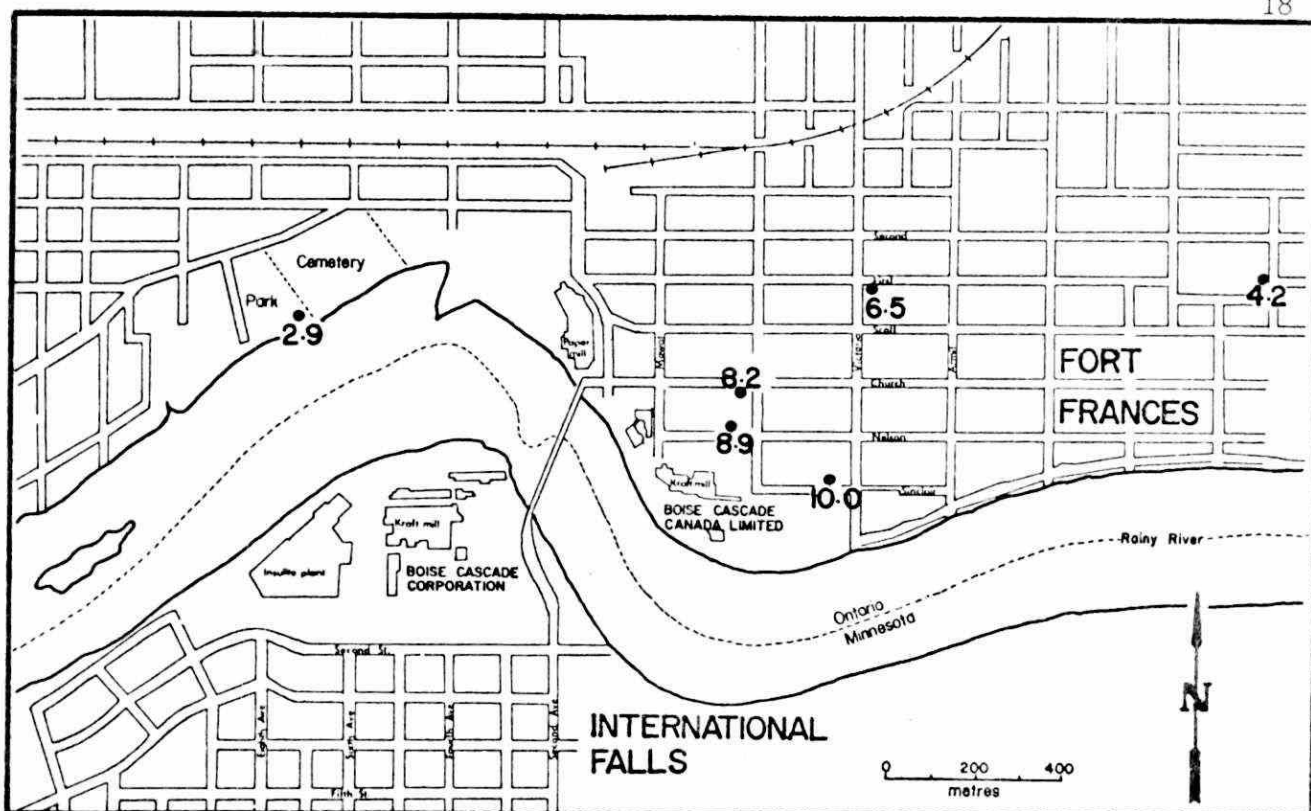


Figure 7a. Average dustfall ( $\text{g}/\text{m}^2/30 \text{ days}$ ), 1978.

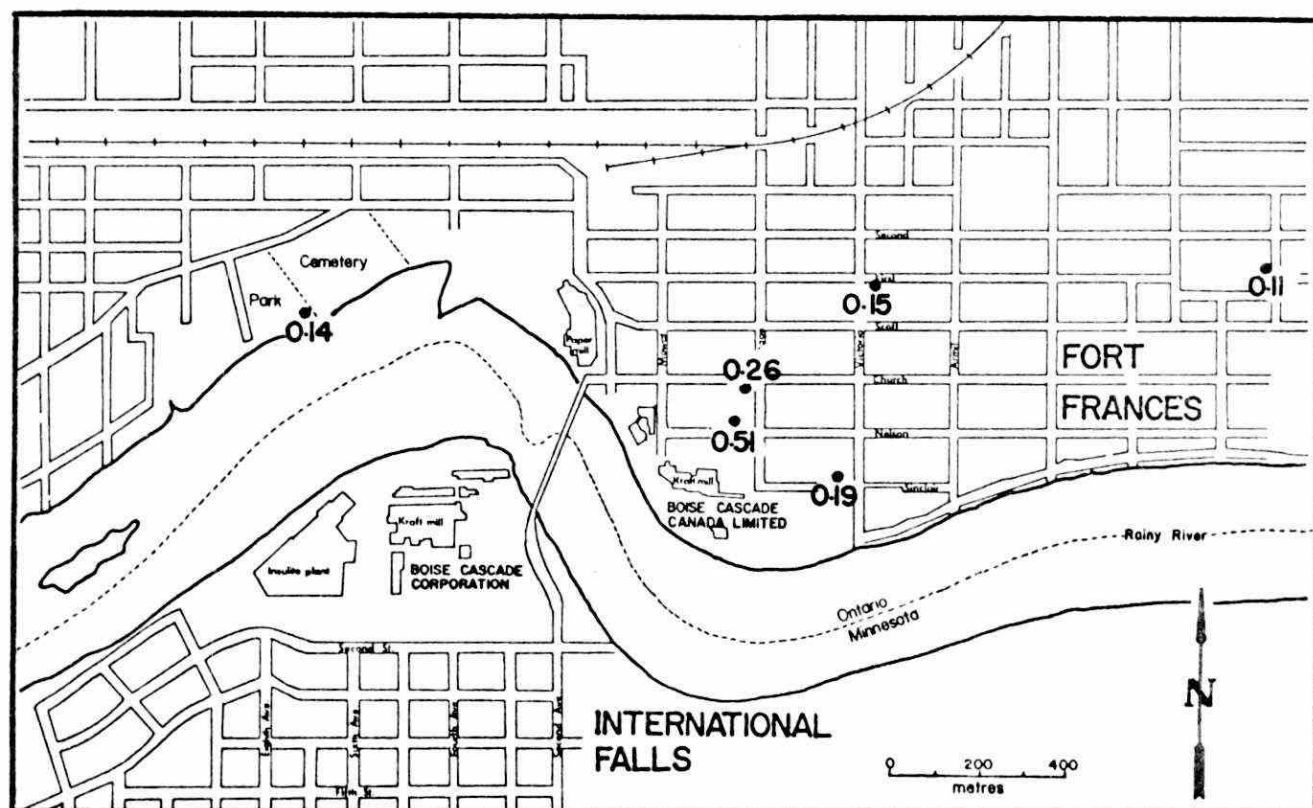


Figure 7b. Average sulphation rate ( $\text{mg SO}_3/100 \text{ cm}^2/\text{day}$ ), 1978.

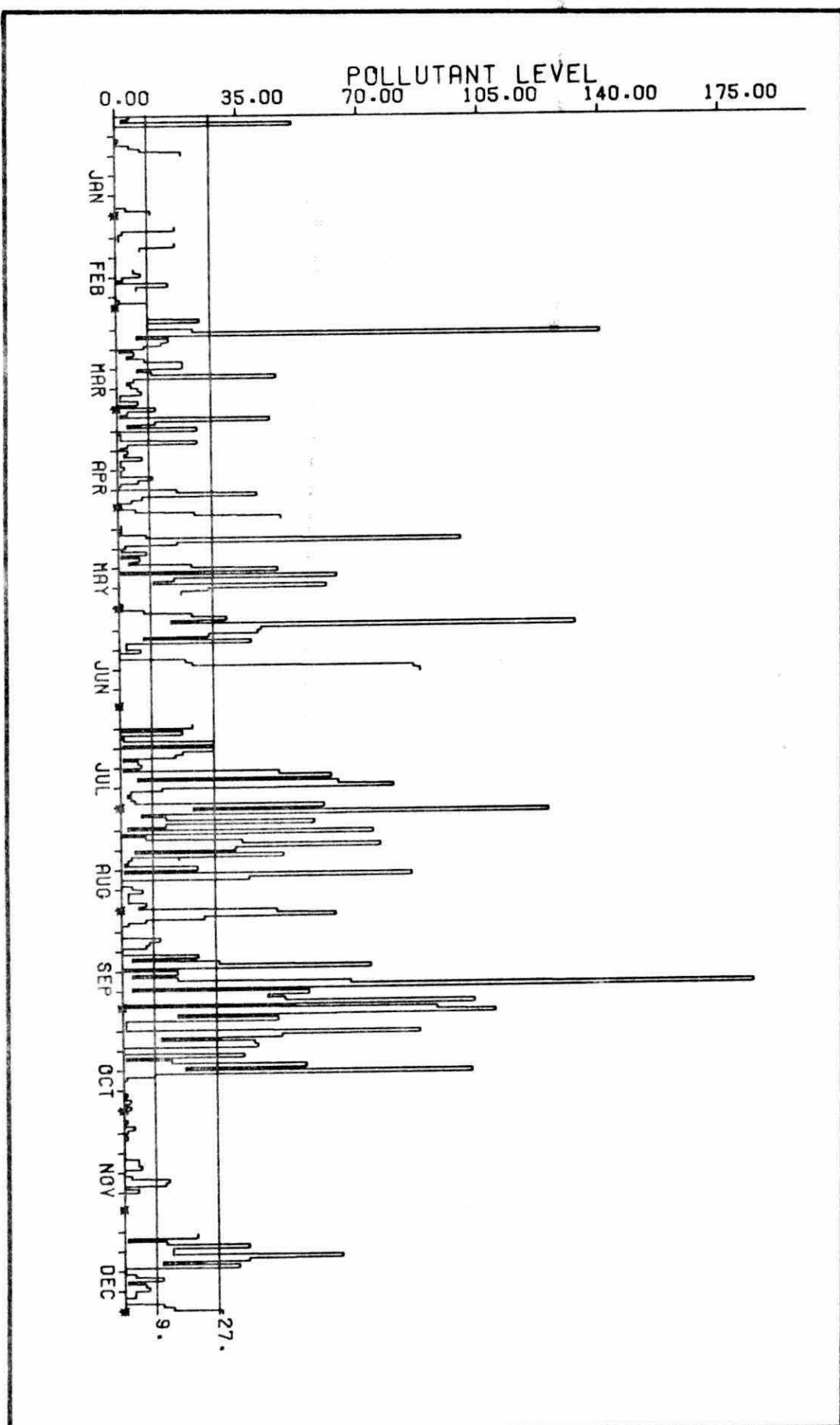


Figure 8. Daily mean TRS concentrations ( parts per billion ) , station 62030 , Fort Frances , 1978.

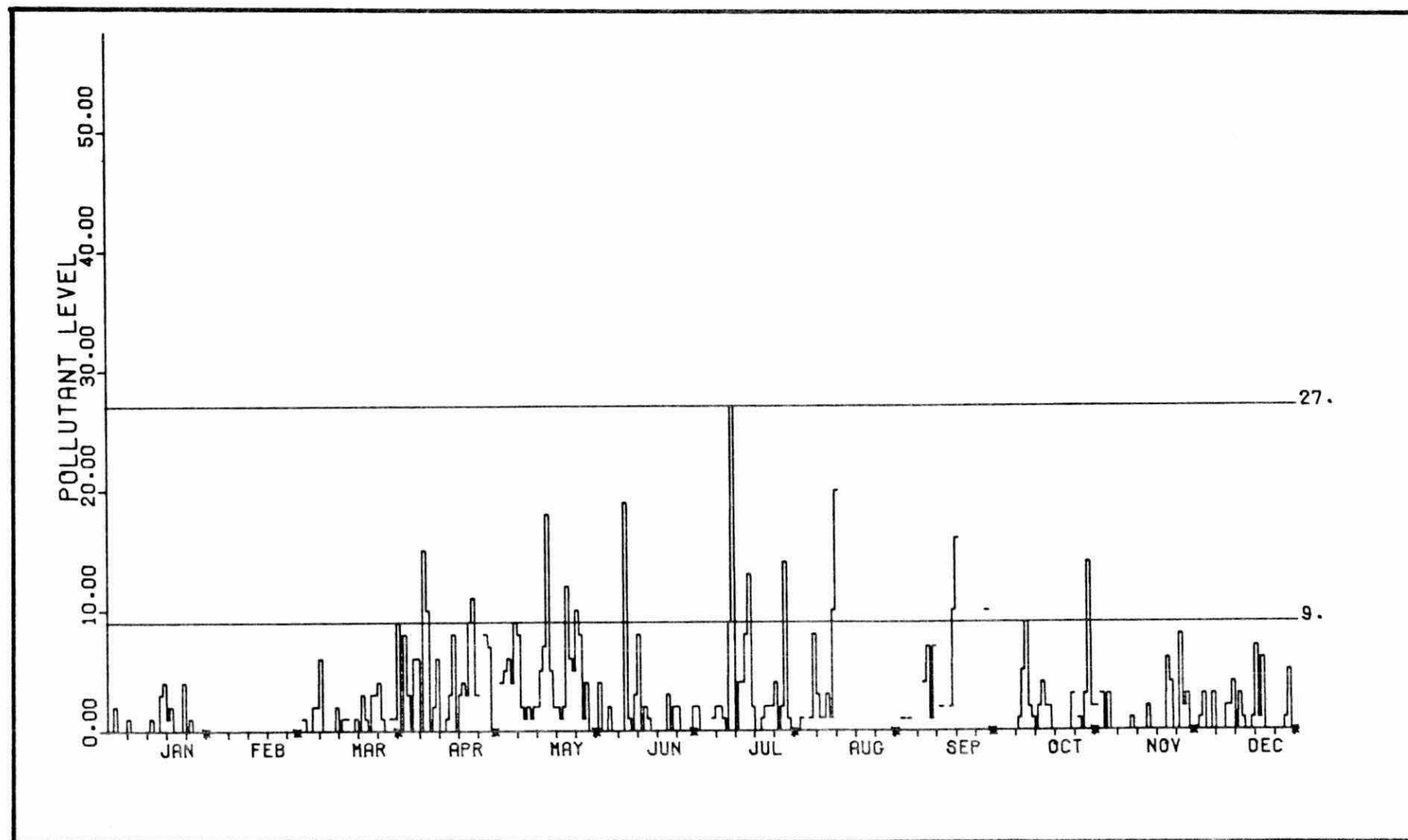


Figure 9. Daily mean TRS concentrations (parts per billion), station 62032, Fort Frances, 1978.



TABLE 1. Average chloride and sodium concentrations in unwashed Manitoba maple foliage<sup>a</sup>, Fort Frances-International Falls, 1975-1978.

Site	Chloride (% dry weight)				Sodium (µg/g, dry weight)			
	1975	1976	1977	1978	1975	1976	1977	1978
1	.26	.29	.37	.33	540	770	2200	1100
2	.09	.14	.12	.13	330	580	370	630
3	.07	.13	.06	.08	250	170	180	98
5	.18	.14	.09	.12	200	120	130	110
7	.22	.15	.16	.29	640	390	550	210
8	.13	.12	.13	.07	190	150	140	43
9	.12	.16	.06	.07	180	180	230	97
12	.36	.16	.32	.53	1500	1300	2300	2600
13	.37	.16	.18	.22	460	1100	600	400
14	.33	.14	.20	.19	400	120	140	170
15	.08	.09	.07	.14	320	100	150	120
16	.15	.14	.12	.16	500	140	300	82
17	.11	.13	.13	.10	370	180	320	100
19	.08	.10	.12	.07	350	180	140	67
20	.11	.11	.08	.07	310	120	250	46
21	.07	.08	.06	.08	560	130	140	53
23	.04	.03	.04	.02	1500	160	100	72
25	.09	.12	.09	.08	360	77	98	32
27	.13	.12	.05	.04	1000	140	290	53
28	.13	.17	.09	.11	310	220	160	72
29	.05	.08	.06	.08	700	150	150	95
30	.05	.07	.05	.05	180	97	230	58
31	.10	.07	.04	.05	280	100	140	71
32	.03	.06	.03	.06	170	97	94	43
Controls	.04	.05	.06	.05	70	76	52	38

<sup>a</sup>Values for 1975 are averages of three sets of triplicate samples. Data for 1976 to 1978 are averages of one set of triplicate samples.

TABLE 2. Average concentrations of calcium, chloride, sodium and sulphate (all in mg/l) in meltwater from snow samples collected from 1974 to 1977, and in March, 1978, in Fort Frances and International Falls.

Site	Calcium		Chloride		Sodium		Sulphate	
	1974-77	1978	1974-77	1978	1974-77	1978	1974-77	1978
1	50	23	16	7	81	30	160	58
2	6	8	6	2	24	7	28	13
3	14	7	4	2	27	14	51	27
4	2	5	2	2	18	23	37	43
5	13	11	4	2	38	20	81	37
6	5	10	1	2	11	25	36	49
7	10	34	4	7	22	22	34	38
8	5	13	4	2	6	14	11	26
9	5	8	<1	4	4	18	8	31
10	4	6	2	2	29	15	59	25
11	2	2	1	8	12	3	22	6
Controls	<1	2	<1	1	<1	6	2	11
Guideline	5		5		10		10	

TABLE 3. Average levels of acidity, alkalinity, conductivity, tannins and suspended solids in meltwater from snow sampled from Fort Frances and International Falls in March, 1978.

Site	Acidity (mg/l)	Alkalinity (mg/l)	Conductivity ( $\mu$ mhos/cm)	Tannins (mg/l)	Suspended Solids (mg/l)
1	0	55	275	1	300
2	0	17	80	<1	62
3	1	15	112	1	75
4	1	14	150	<1	28
5	0	22	154	2	210
6	0	22	189	1	110
7	0	92	272	8	1975
8	0	26	134	1	230
9	0	20	136	<1	88
10	0	15	109	<1	45
11	1	3	29	<1	15
Controls	2	4	48	<1	15

Table 4. Total dustfall ( $\text{g/m}^2/30$  days), Fort Frances, 1978.

Station	Location	Distance (metres) and direction from source <sup>a</sup>													Mean
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
62030	Church/Portage	215 NNE	4.2	3.6	<u>12.1</u> <sup>b</sup>	<u>14.3</u>	<u>10.4</u>	<u>9.2</u>	<u>11.7</u>	<u>9.1</u>	<u>11.1</u>	5.6	3.7	3.9	<u>8.2</u>
62032	Cemetery	990 WNW	2.5	2.2	-	3.2	4.3	3.9	2.5	4.0	3.7	1.2	2.9	1.4	2.9
62033	Nelson/Portage	135 NNE	6.6	5.2	<u>7.6</u>	<u>9.2</u>	<u>10.0</u>	<u>12.4</u>	<u>14.0</u>	<u>8.2</u>	<u>17.2</u>	5.1	6.1	5.5	<u>8.9</u>
62034	First/Victoria	590 NE	2.6	2.4	<u>8.7</u>	<u>7.3</u>	<u>7.1</u>	<u>9.3</u>	<u>7.6</u>	<u>7.4</u>	<u>10.4</u>	<u>7.3</u>	4.9	2.8	<u>6.5</u>
62035	Legion Building	250 N	5.1	3.1	<u>11.3</u>	<u>11.3</u>	7.7	<u>10.1</u>							
62036	Sinclair/Victoria	295 E	6.2	<u>9.0</u>	-	<u>11.1</u>	<u>11.2</u>	<u>12.9</u>	<u>12.2</u>	<u>15.2</u>	<u>15.0</u>	6.1	4.9	6.1	<u>10.0</u>
62037	Reid/Gillon	1385 E	3.1	1.8	4.9	6.5	6.6	4.4	3.4	<u>7.8</u>	5.7	1.8	1.6	2.3	4.2
62046	Sinclair/Portage	150 E							<u>13.3</u>	<u>9.8</u>	<u>13.3</u>	5.4	6.4	<u>8.3</u>	

<sup>a</sup>Source arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack.

<sup>b</sup>Values exceeding maximum acceptable level of 7.0 (monthly) or 4.6 (annual average) are underlined.

TABLE 5. Soluble calcium ( $\text{g/m}^2/30$  days) in dustfall, Fort Frances, 1978.

Station	Location	Distance (metres) and direction from source <sup>a</sup>													Mean
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
62030	Church/Portage	215 NNE	0.4	0.2	0.6	0.2	0.4	0.7	0.7	0.6	0.8	0.2	0.2	0.4	0.5
62032	Cemetery	990 WNW	0.1	0.1	-	0.1	0.2	0.3	0.3	0.2	0.2	0.2	<0.1	0.1	0.2
62033	Nelson/Portage	135 NNE	0.6	0.4	0.7	0.3	0.6	1.2	1.2	0.8	1.1	0.5	0.5	0.7	0.7
62034	First/Victoria	590 NE	0.1	0.1	0.4	0.1	0.2	0.4	0.3	0.3	0.6	0.3	0.2	0.2	0.3
62035	Legion Building	250 N	0.5	0.2	0.6	0.2	0.3	0.7							
62036	Sinclair/Victoria	295 E	0.2	0.3	-	0.3	0.3	0.7	0.6	0.5	1.1	0.2	0.3	0.4	0.4
62037	Reid/Gillon	1385 E	<0.1	0.1	0.3	0.2	0.3	0.2	0.2	0.2	0.3	0.1	<0.1	<0.1	0.2
62046	Sinclair/Portage	150 E							1.2	1.3	0.9	0.2	0.6	0.8	

<sup>a</sup>Source arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack.

TABLE 6. Soluble sodium ( $\text{g/m}^2/30$  days) in dustfall, Fort Frances, 1978.

Station	Location	Distance (metres) and direction from source <sup>a</sup>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	0.4	0.3	0.2	0.2	0.5	0.8	0.6	0.2	0.6	-	0.2	0.2	0.4
62032	Cemetery	990 WNW	0.2	0.1	-	0.1	0.1	0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1
62033	Nelson/Portage	135 NNE	0.8	0.4	0.3	0.5	0.9	1.2	1.3	0.4	1.8	0.2	0.7	1.1	0.8
62034	First/Victoria	590 NE	0.4	0.4	0.1	0.1	0.2	0.6	0.2	0.1	0.2	<0.1	<0.1	0.2	0.2
62035	Legion Building	250 N	0.4	0.3	0.3	0.1	0.4	0.8							
62036	Sinclair/Victoria	295 E	0.6	1.1	-	0.2	0.2	0.5	0.4	0.3	0.3	<0.1	0.1	0.3	0.4
62037	Reid/Gillon	1385 E	0.6	0.3	0.1	0.1	0.1	0.2	0.1	0.1	<0.1	<0.1	<0.1	0.1	0.2
62046	Sinclair/Portage	150 E							0.6	0.4	0.3	<0.1	0.3	1.4	

<sup>a</sup>Source arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack.

TABLE 7. Soluble sulphate ( $\text{g/m}^2/30$  days) in dustfall, Fort Frances, 1978.

Station	Location	Distance (metres) and direction from source <sup>a</sup>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	0.8	0.5	0.6	0.5	1.5	1.8	1.7	0.7	1.6	0.4	0.6	0.6	0.9
62032	Cemetery	990 WNW	0.4	0.3	-	0.3	0.7	0.4	0.5	0.8	0.7	-	0.2	0.1	0.4
62033	Nelson/Portage	135 NNE	1.9	1.1	1.2	1.4	2.6	3.2	3.7	1.4	5.6	-	2.0	1.5	2.3
62034	First/Victoria	590 NE	0.8	0.7	0.5	0.3	0.8	1.4	0.8	0.6	0.7	0.1	0.4	0.6	0.6
62035	Legion Building	250 N	1.0	0.6	1.0	0.4	1.3	1.8							
62036	Sinclair/Victoria	295 E	1.4	2.4	-	0.5	1.3	1.2	1.5	0.9	1.4	0.2	0.6	0.9	1.1
62037	Reid/Gillon	1385 E	1.1	0.6	0.4	0.4	0.7	0.7	0.4	0.6	0.6	0.1	0.2	0.3	0.5
62046	Sinclair/Portage	150 E							1.6	0.4	1.2	0.3	1.0	1.5	

<sup>a</sup>Source arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack.

TABLE 8. Total suspended particulate ( $\mu\text{g}/\text{m}^3$ ), Fort Frances, 1978.

Date	Stations		Wind <sup>a</sup>	Date	Stations		Wind
	62030	62032			62030	62032	
Jan 2	-	11	300	Jul 1	52	84	100
8	12	9	300	7	61	53	340
14	25	23	100	13	63	23	290
20	84	56	40	19	40	26	20
26	15	9	330	25	65	39	240
				31	45	25	300
Feb 1	23	20	290	Aug 6	43	40	150
7	23	6	80	12	96	-	240
13	13	12	10	18	59	26	250
19	34	32	80	24	61	34	120
25	16	12	300	30	69	29	290
Mar 3	54	21	300	Sep 5	67	44	190
9	45	21	270	11	-	21	80
15	76	36	310	17	76	25	190
21	110 <sup>b</sup>	-	200	23	175	35	210
27	<u>164<sup>b</sup></u>	52	270	29	<u>49</u>	24	50
Apr 2	23	64	120	Oct 5	24	8	330
8	<u>159</u>	61	120	11	<u>150</u>	68	240
14	<u>190</u>	63	300	17	<u>138</u>	34	230
20	<u>171</u>	56	30	23	<u>49</u>	36	200
26	<u>204</u>	91	50	29	55	64	160
May 2	<u>293</u>	<u>153</u>	270	Nov 4	34	52	140
8	<u>43</u>	<u>27</u>	40	10	49	34	40
14	55	34	20	16	84	48	170
20	47	29	360	22	<u>145</u>	-	150
26	86	-	140	28	<u>27</u>	38	150
Jun 1	36	21	90	Dec 4	92	28	230
7	-	44	40	10	68	34	160
13	67	82	70	16	45	11	260
19	<u>337</u>	51	180	22	24	18	290
25	<u>51</u>	34	120	28	16	9	80

<sup>a</sup>Prevailing wind direction, degrees, recorded 6.4 m above ground level at International Falls airport.

<sup>b</sup>Values exceeding maximum acceptable level of  $120 \mu\text{g}/\text{m}^3$  (24-hour average) are underlined.



TABLE 9. Sulphation rates ( $\text{mg SO}_3/100 \text{ cm}^2/\text{day}$ ), Fort Frances, 1978.

Station	Location	Distance (metres) and direction from source <sup>a</sup>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
62030	Church/Portage	215 NNE	.26	.17	.17	.08	.24	.16	.24	.49	.48	-	.32	.26	.26
62032	Cemetery	990 WNW	.17	.09	.14	.09	.15	.11	.15	.26	.19	-	.11	.13	.14
62033	Nelson/Portage	135 NNE	.36	.25	.32	.15	.48	.51	.71	.91	1.38	.37	.25	.43	.51
62034	First/Victoria	590 NE	.21	.07	.11	.04	.08	.30	.07	.18	.22	.16	.14	.19	.15
62035	Legion Building	250 N	.40	.15	.22	.09	.24	.25							
62036	Sinclair/Victoria	295 E	.21	.27	.18	.07	.06	.09	.27	.21	.35	-	.15	.21	.19
62037	Reid/Gillon	1385 E	.25	.09	.10	.04	<.01	.09	.05	.07	.12	.12	.16	.19	.11
62046	Sinclair/Portage	150 E							.57	.21	.40	.22	.27	.36	

<sup>a</sup>Source arbitrarily designated as Boise Cascade Canada Limited kraft mill recovery furnace stack.

TABLE 10. Distribution of total reduced sulphur readings (ppb, hourly averages) in Fort Frances, 1978.

Month	Days of data	Number of readings for concentrations of:						Maximum values:	
		0-10	11-27	28-50	51-100	101-500	>500	Hour	Day
Station 62030									
Jan	15	335	15	4	10	5	0	116	51
Feb	16	401	28	12	6	3	0	141	17
Mar	29	522	107	34	21	24	0	263	140
Apr	30	615	50	19	17	11	0	201	44
May	27	499	58	32	32	44	0	233	99
Jun	19	324	37	23	31	53	0	332	132
Jul	26	448	55	42	51	32	0	260	79
Aug	31	514	60	41	65	55	0	278	124
Sep	30	492	66	37	44	71	1	540	183
Oct	31	574	45	37	31	42	1	526	108
Nov	26	590	17	12	2	0	0	54	13
Dec	24	392	82	44	35	11	0	275	63
Year	304	5706	620	337	345	327	2	540	183
Station 62032									
Jan	29	684	10	2	1	0	0	52	4
Feb				no data					
Mar	28	643	17	2	1	0	0	62	9
Apr	27	543	59	24	3	0	0	72	15
May	30	637	56	28	4	0	0	65	18
Jun	30	668	16	5	3	2	0	120	19
Jul	29	601	42	11	6	2	0	103	27
Aug	11	239	19	4	3	1	0	106	20
Sep	11	317	39	12	9	1	0	116	16
Oct	26	502	22	7	1	1	0	134	14
Nov	29	668	19	3	1	0	0	69	8
Dec	31	686	20	4	0	0	0	37	7
Year	281	6188	319	102	32	7	0	134	27

TABLE 11. Directional distribution of hourly readings of total reduced sulphur (TRS) in 1978 at station 62030, Fort Frances.

Wind direction <sup>a</sup>	Number of hours when wind was from the direction indicated	Number of hours when TRS was monitored	Average hourly TRS concentrations (ppb)
10	120	21	1
20	108	19	1
30	76	12	0
40	103	20	1
50	109	19	1
60	122	21	1
70	152	28	1
80	159	32	1
90	140	31	1
100	105	23	1
110	87	13	2
120	285	74	1
130	252	67	2
140	164	50	5
150	181	69	10
160	245	133	17
170	225	149	28
180	355	281	42
190	230	168	55
200	196	161	88
210	152	123	84
220	132	109	72
230	159	130	48
240	212	176	31
250	213	165	19
260	229	173	15
270	303	184	9
280	173	68	6
290	362	156	3
300	623	177	2
310	242	53	3
320	192	72	3
330	165	72	4
340	164	68	3
350	109	30	2
360	110	24	1
Calm	408	282	17

<sup>a</sup>In degrees, measured 6.4 m above ground at International Falls airport.

TABLE 12. Directional distribution of hourly readings of total reduced sulphur (TRS) in 1978 at station 62032, Fort Frances.

Wind Direction <sup>a</sup>	Number of hours when wind was from the direction indicated	Number of hours when TRS was monitored	Average hourly TRS concentrations (ppb)
10	114	22	2
20	109	22	1
30	78	9	1
40	92	12	1
50	101	10	0
60	109	12	1
70	129	12	1
80	121	11	1
90	125	5	1
100	89	13	6
110	82	20	8
120	265	119	11
130	239	94	8
140	150	39	8
150	170	41	8
160	215	49	9
170	196	34	5
180	300	32	2
190	218	14	1
200	175	3	1
210	147	7	1
220	121	6	1
230	149	4	1
240	193	1	0
250	210	5	0
260	220	4	0
270	257	4	0
280	140	2	0
290	295	3	0
300	533	2	0
310	221	8	1
320	179	11	1
330	149	13	1
340	144	11	1
350	101	20	2
360	101	29	2
Calm	401	89	4

<sup>a</sup>In degrees, measured 6.4 m above ground at International Falls airport.

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